Surname	StemUp Model Solution	Centre Number	Candidate Number
Other Names			2

GCE AS

B410U20-1

S19-B410U20-1

CHEMISTRY – AS component 2
Energy, Rate and Chemistry of Carbon Compounds

THURSDAY, 23 MAY 2019 – MORNING

1 hour 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 7.**	**10**	
Section B	**8.**	**14**	
	9.	**14**	
	10.	**15**	
	11.	**10**	
	12.	**17**	
	Total	**80**	

B410U201
01

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a:
- calculator;
- **Data Booklet** supplied by WJEC.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.

Write your name, centre number and candidate number in the spaces at the top of this page.

Section A Answer **all** questions in the spaces provided.
Section B Answer **all** questions in the spaces provided.

Candidates are advised to allocate their time appropriately between **Section A (10 marks)** and **Section B (70 marks)**.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The maximum mark for this paper is 80.

Your answers must be relevant and must make full use of the information given to be awarded full marks for a question.

The assessment of the quality of extended response (QER) will take place in **Q.8***(a)*.

If you run out of space, use the additional page(s) at the back of the booklet, taking care to number the question(s) correctly.

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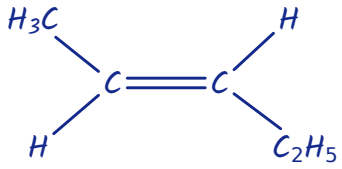
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SECTION A

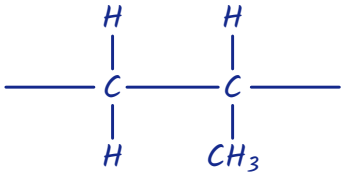
Answer **all** *questions in the spaces provided.*

1. Draw the structure of a hydrocarbon that has five carbon atoms and exhibits *E-Z* isomerism. [1]



(E)-pent-2-ene

2. Draw the repeat unit of the polymer formed from the monomer CH_3CHCH_2. [1]



3. Species can be classified as electrophiles, nucleophiles or radicals.

(a) Explain what is meant by an *electrophile*. [1]

A species that can accept a pair of electrons (an electron deficient species).

(b) Give an example of an electrophile. [1]

H^+ (or $Br^{\delta+}$ in Br_2, NO_2^+)

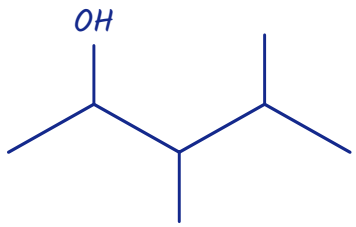
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4. 3,4-Dimethylpentan-2-ol is a secondary alcohol.

(a) Draw the **skeletal** formula for 3,4-dimethylpentan-2-ol. [1]



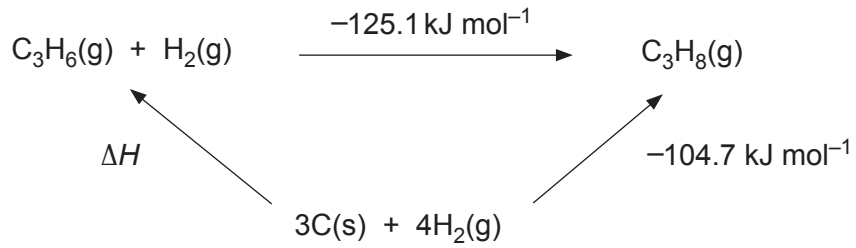
(b) State why it is classified as a secondary alcohol. [1]

The carbon atom bonded to the –OH group is joined to two other carbon atoms (and one H atom).

5. *(a)* State Hess's Law. [1]

The total enthalpy change for a reaction is independent of the route taken from the reactants to the products.

(b) Determine the value of ΔH, in kJ mol^{-1}, in the energy cycle below. [1]



$\Delta H + (-125.1) = -104.7$

$\Delta H = -104.7 + 125.1 = +20.4$ kJ mol^{-1}

ΔH = +20.4 kJ mol^{-1}

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6. Name **two** compounds formed during the **incomplete** combustion of propane. [1]

carbon monoxide (CO) and water (H_2O)

7. Ethanoic acid, CH_3COOH, is a typical organic acid.

Write the equation for the reaction between ethanoic acid and magnesium oxide. [1]

$2CH_3COOH + MgO \rightarrow (CH_3COO)_2Mg + H_2O$

10

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SECTION B

Answer **all** *questions in the spaces provided.*

8. *(a)* Discuss how 1-bromobutane can react with hydroxide ions under different conditions to give two different organic products.

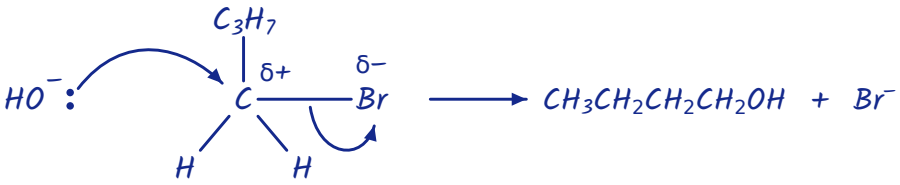
Draw the mechanism for the formation of **one** of the organic products. [6 QER]

1-Bromobutane reacts with hydroxide ions in two ways depending on the solvent. The C–Br bond is polar ($C^{\delta+}$–$Br^{\delta-}$) as Br is more electronegative than C. Nucleophilic substitution: warm (reflux) with NaOH dissolved in water (aqueous NaOH). The OH^- acts as a nucleophile: its lone pair attacks the δ+ carbon, the C–Br bond breaks heterolytically and Br^- leaves. The product is butan-1-ol:

$CH_3CH_2CH_2CH_2Br + OH^- \rightarrow CH_3CH_2CH_2CH_2OH + Br^-$

Elimination: heat (reflux) with NaOH dissolved in ethanol (ethanolic NaOH).

Mechanism (nucleophilic substitution):



In elimination OH^- acts as a base: it removes an H^+ from the carbon next to the C–Br carbon, a C=C double bond forms and Br^- leaves, so HBr is eliminated. The product is but-1-ene:

$CH_3CH_2CH_2CH_2Br + OH^- \rightarrow CH_3CH_2CH{=}CH_2 + H_2O + Br^-$

So water as solvent favours substitution (alcohol), while ethanol as solvent and a higher temperature favour elimination (alkene).

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(b) Chloroethane is formed when ethane reacts with chlorine in sunlight. However, during the reaction a mixture of products is obtained.

(i) Name the type of reaction mechanism taking place. [1]

radical substitution (photochlorination)

(ii) Explain why butane can also form during this reaction. [2]

Ethyl radicals form when a chlorine radical removes H from ethane: C_2H_6 + $Cl\cdot \rightarrow \cdot C_2H_5 + HCl$.

In a termination step two ethyl radicals combine: $\cdot C_2H_5 + \cdot C_2H_5 \rightarrow C_4H_{10}$ (butane).

(c) Halogenoalkanes can also be formed from alkenes.

When 3-methylbut-1-ene is reacted with hydrogen bromide a mixture of two different products is formed.

(i) Identify the products. [2]

1-bromo-3-methylbutane, $CH_2BrCH_2CH(CH_3)_2$

2-bromo-3-methylbutane, $CH_3CHBrCH(CH_3)_2$

(ii) State and explain which of the two products is more likely to be formed. [1]

2-bromo-3-methylbutane, since it forms via the secondary carbocation intermediate, which is more stable than the primary carbocation.

(d) Halogenoalkanes containing both chlorine and fluorine are known as CFCs. One of the most abundant CFCs in the atmosphere is trichlorofluoromethane, CCl_3F.

Explain why CCl_3F remains longer in the troposphere (lower atmosphere) of the Earth than in the stratosphere (upper atmosphere). [2]

CCl_3F is very stable: the C–F and C–Cl bonds are strong and the UV light in the lower atmosphere does not have enough energy to break them, so it does not break down there. In the stratosphere higher energy UV light breaks the C–Cl bond, forming chlorine radicals, so it is destroyed there.

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14

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9. A student carried out an experiment to determine the enthalpy change of reaction for the decomposition of aqueous hydrogen peroxide.

$$H_2O_2(aq) \longrightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Since the reaction is very slow, she was told to use aqueous iron(III) nitrate as a catalyst. It is an amber colour originally but turns a dark reddish-brown during the decomposition.

She used the following method.

- Use a burette to measure 50.0 cm^3 of aqueous hydrogen peroxide (3 % w/v) into a polystyrene cup.
- Place a 1 °C graduated thermometer in the solution and record the temperature.
- Add 50.0 cm^3 of aqueous iron(III) nitrate to the solution.
- Stir the mixture with the thermometer and record the maximum temperature reached.

Her results are shown below.

Initial temperature of the aqueous hydrogen peroxide = 19.0 °C

Final temperature of the aqueous hydrogen peroxide = 27.5 °C

(a) The student said that it is not necessary to ensure that the hydrogen peroxide and the iron(III) nitrate are at the same temperature before addition.

Is she correct? Justify your answer. [1]

No. Adding the catalyst solution at a different temperature would itself cause a temperature change that has nothing to do with the reaction.

(b) A concentration of "3 % w/v" means that there are 3 g of hydrogen peroxide in 100 cm^3 of solution.

Calculate the concentration of the aqueous hydrogen peroxide in mol dm^{-3}. [2]

$M_r\ H_2O_2 = 34.02$

moles H_2O_2 in 100 cm^3 = $3 \div 34.02 = 8.82 \times 10^{-2}$ mol

concentration = $8.82 \times 10^{-2} \times (1000 \div 100) = 0.882$ mol dm^{-3}

Concentration = 0.882 mol dm^{-3}

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(c) Calculate the value, in kJ mol^{-1}, for the enthalpy change of reaction for the decomposition of hydrogen peroxide.

Give your answer to an **appropriate** number of significant figures. [4]

(If you do not have an answer in part *(b)* assume that the concentration is 0.790 mol dm^{-3}. This is **not** the correct answer.)

mass of solution = 50.0 + 50.0 = 100 g; ΔT = 27.5 − 19.0 = 8.5 °C

$q = mc\Delta T = 100 \times 4.18 \times 8.5 = 3553$ J

$n(H_2O_2) = 0.882 \times 50.0 \div 1000 = 4.41 \times 10^{-2}$ mol

$\Delta H = -q \div n = -3553 \div 4.41 \times 10^{-2} = -80\,570$ J mol^{-1}

$\Delta H = -80.6$ kJ mol^{-1} (3 sig figs)

ΔH = −80.6 kJ mol^{-1}

(d) State why she accurately measured the volume of the catalyst. [1]

The mass of the whole solution (including the catalyst) is used in $q = mc\Delta T$ to calculate the heat transferred, so the total volume must be known accurately.

(e) State how the student would know that the decomposition reaction had finished. [1]

No more bubbles of gas (oxygen) are given off, or the colour of the catalyst returns to amber.

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(f) Suggest **two** improvements that would make the experiment more accurate. Justify both improvements. [4]

1. *Place a lid on the polystyrene cup: this prevents heat loss to the surroundings, so the measured temperature rise is closer to the true value.*

2. *Plot a cooling curve (temperature against time) and extrapolate back to the time of mixing: this gives the temperature that would have been reached if the reaction occurred instantly with no heat loss.*

(g) State how the value of the enthalpy change would be affected if the experiment were repeated using a different catalyst. [1]

No change, because a catalyst does not affect the enthalpy change of a reaction (it only lowers the activation energy).

14

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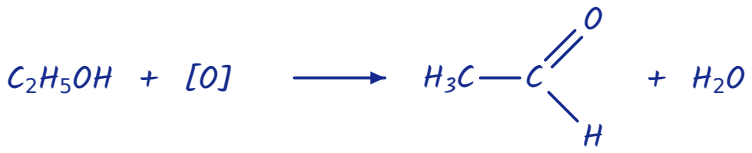
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10. *(a)* A student is asked to prepare a sample of ethanal by oxidising ethanol.

(i) Write an equation for this reaction. [1]

Use [O] to represent the oxidising agent and show the structure of the organic product.



(ii) Describe, giving brief experimental details, how he can carry out the reaction. [4]

Place dilute sulfuric acid in a flask and add sodium dichromate(VI), shaking until it has dissolved.

Cool the mixture, then add the ethanol dropwise, shaking between additions.

Set up the apparatus for distillation (condenser and a receiving flask cooled in ice).

Heat gently so that the ethanal boils over (distils off) as soon as it forms and collect the liquid; this stops it being oxidised further to ethanoic acid.

(iii) Ethanol can also be oxidised to ethanoic acid. Describe how the student could use a chemical test to confirm that his sample of ethanal did **not** contain ethanoic acid. [2]

Add sodium hydrogencarbonate (or sodium carbonate) to a sample of the product.

No effervescence (no CO_2 given off) shows that no ethanoic acid is present.

(b) State a difference and a similarity between the ^{13}C NMR spectra of ethanal and ethanol. [2]

Difference *Ethanol has a peak at 50 to 90 ppm (C–O) that ethanal does not; ethanal has a peak at 190 to 220 ppm (C=O) that ethanol does not.*

Similarity *Both spectra have two peaks, each with one peak below 40 ppm (the CH_3 carbon).*

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(c) Ethanol is widely used as a biofuel in some countries.

(i) The equation for its combustion is given below.

$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

Use the average bond enthalpy values given in the table below to calculate the enthalpy of combustion for ethanol. [3]

Bond	Average bond enthalpy / kJ mol^{-1}
C—C	348
C—H	412
C—O	360
O—H	463
O═O	496
C═O	743

bonds broken: 5(C–H) + (C–C) + (C–O) + (O–H) + 3(O=O)

= (5 × 412) + 348 + 360 + 463 + (3 × 496) = 4719 kJ

bonds formed: 4(C=O) + 6(O–H) = (4 × 743) + (6 × 463) = 5750 kJ

ΔH = bonds broken – bonds formed = 4719 – 5750 = –1031 kJ mol^{-1}

$\Delta_c H$ ethanol = −1031 kJ mol^{-1}

(ii) Give a disadvantage of biofuels compared with fossil-based fuels. [1]

Large areas of land (and large amounts of water and fertiliser) are needed to grow the crops, land that could be used to grow food.

(d) Ethanol and hexan-1-ol are both primary alcohols. Explain why ethanol is soluble in water but hexan-1-ol is not. [2]

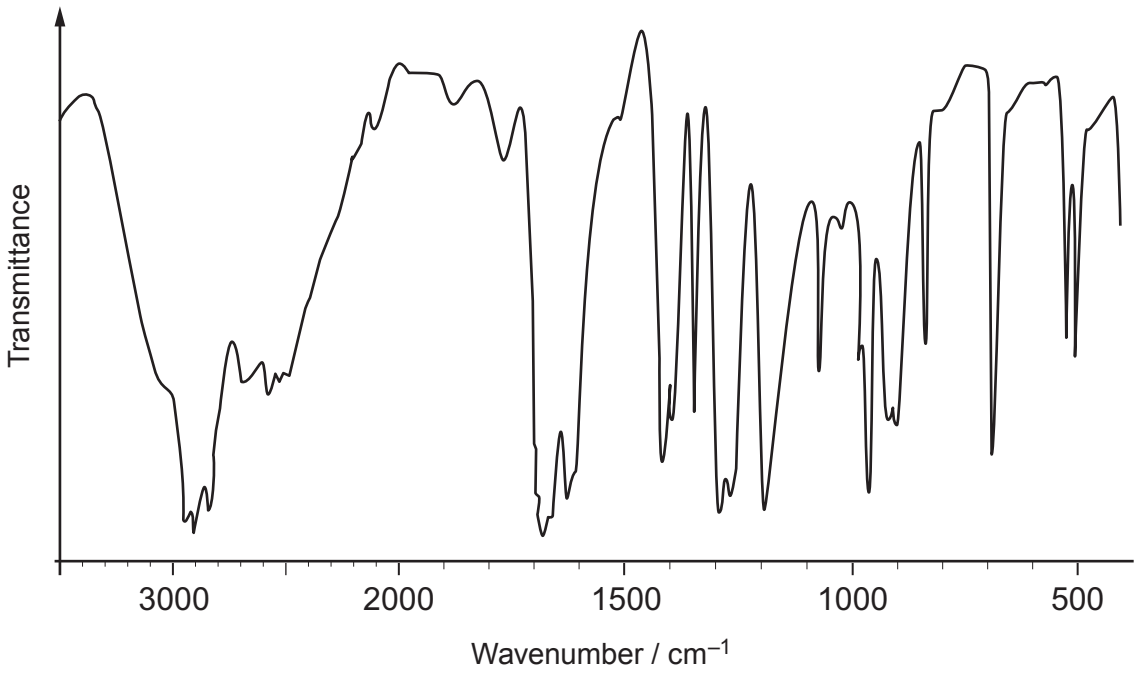
Ethanol's –OH group forms hydrogen bonds with water molecules, so it is soluble. In hexan-1-ol the carbon chain is much longer, so the effect of the –OH group is now small: the long non-polar chain cannot hydrogen bond to water, so it is insoluble.

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11. Compound **A** contains 55.8 % carbon, 7.00 % hydrogen and 37.2 % oxygen by mass.

Part of its infrared spectrum is shown below.



- An aqueous solution of compound **A** has a pH of less than 7.
- In an addition reaction, 2.00 g of compound **A** reacts with 3.71 g of bromine in a 1 : 1 molar ratio.

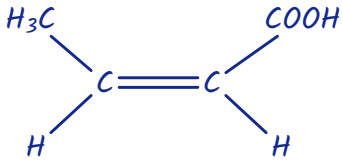
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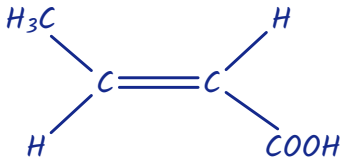
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Use all the data given to identify **all** the possible structures of compound **A**. Explain what information can be found from each piece of data. [10]

$CH_2=CHCH_2COOH$ (but-3-enoic acid) $CH_2=C(CH_3)COOH$ (2-methylpropenoic acid)



Z-but-2-enoic acid



E-but-2-enoic acid

Empirical formula: C : H : O = 55.8/12.0 : 7.00/1.01 : 37.2/16.0 = 4.65 : 6.93 : 2.325 = 2 : 3 : 1, so the empirical formula is C_2H_3O.

IR: a very broad absorption from about 2500 to 3300 cm^{-1} (O–H of a carboxylic acid) and a strong peak at about 1700 cm^{-1} (C=O), so A is a carboxylic acid.

pH < 7: A is an acid, so it must contain a COOH group, i.e. at least two O atoms.

Addition reaction with bromine: A contains a C=C double bond; the 1 : 1 molar ratio shows there is only one C=C bond.

$n(Br_2) = 3.71 \div 159.8 = 2.32 \times 10^{-2}$ mol = n(A), so M_r of A = $2.00 \div 2.32 \times 10^{-2} = 86.2$

M_r of C_2H_3O = 43.0 and $86.2 \div 43.0 = 2$, so the molecular formula is $C_4H_6O_2$.

So A is an unsaturated carboxylic acid with one C=C, C_3H_5COOH. The possible structures (shown above) are $CH_2=CHCH_2COOH$, $CH_2=C(CH_3)COOH$, and Z- and E-$CH_3CH=CHCOOH$ (but-2-enoic acid shows E-Z isomerism as each carbon of the C=C has two different groups).

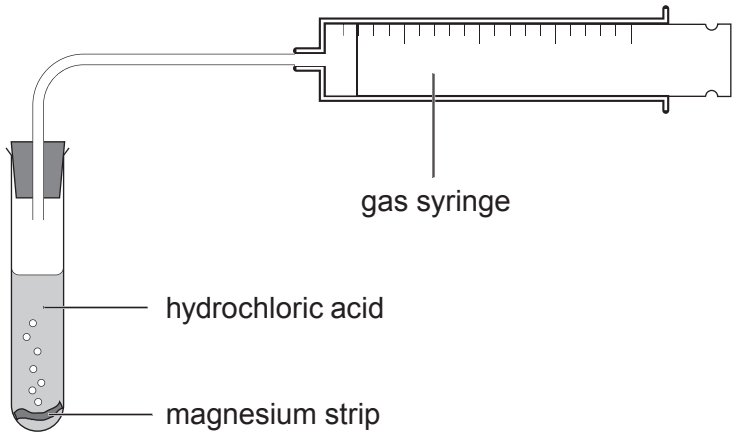
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12. A student carried out an experiment to study the reaction between magnesium and hydrochloric acid.

$$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g) \qquad \Delta H = -467 \text{ kJ mol}^{-1}$$

He used the following apparatus to measure the volume of hydrogen produced over time.



The experiment was carried out at a temperature of 25 °C and 1 atm pressure. The amount of acid used was sufficient to react with all the magnesium.

These are the results obtained.

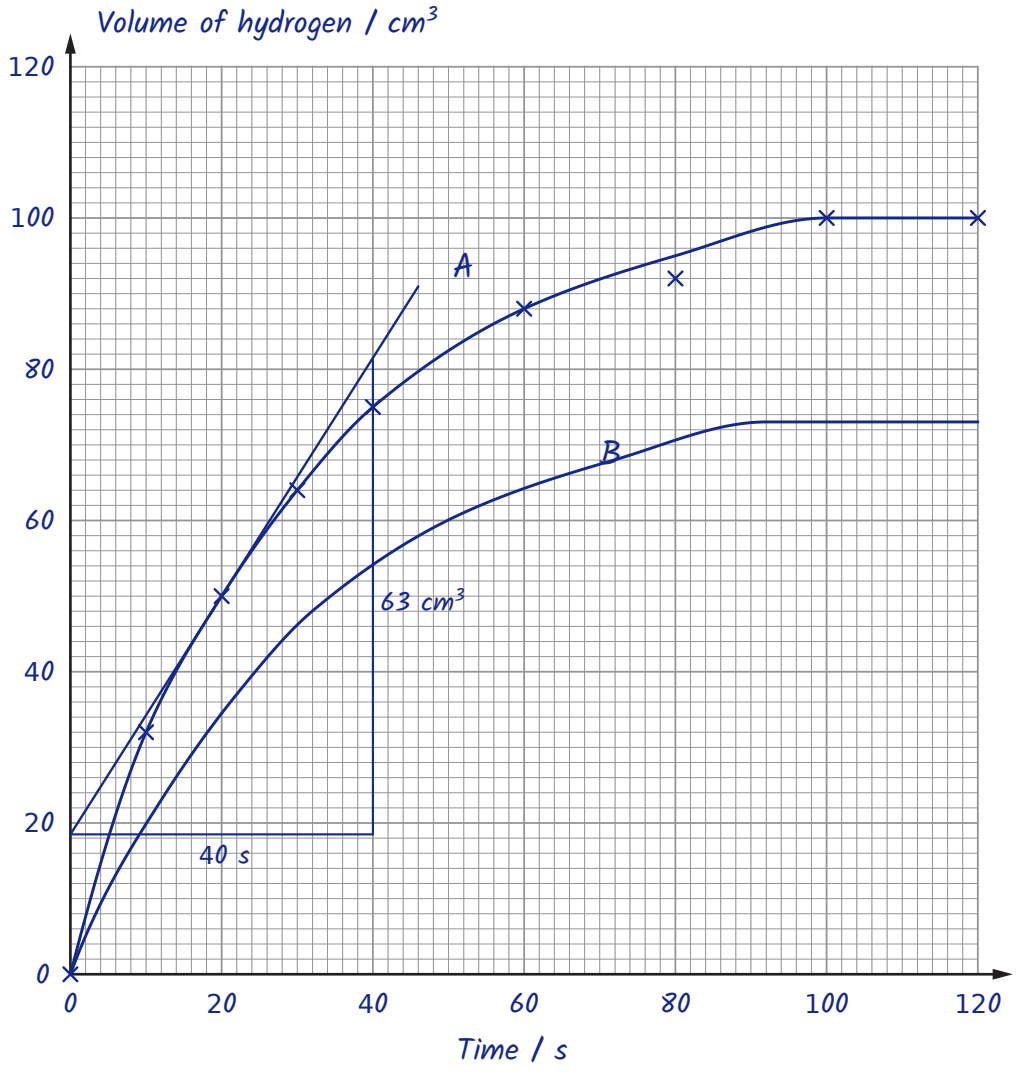
Time / s	Volume of hydrogen / cm^3
0	0
10	32
20	50
30	64
40	75
60	88
80	92
100	100
120	100

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(a) Plot the results for the experiment and draw a line of best fit. Label it **A**. [4]



(b) Use the graph to calculate the rate of reaction at 20 seconds in $cm^3\ s^{-1}$. [2]

tangent drawn at t = 20 s

gradient = (81.5 − 18.5) ÷ (40 − 0) = 63 ÷ 40 = 1.58 $cm^3\ s^{-1}$

Rate = 1.58 ..... $cm^3\ s^{-1}$

(c) When he repeated the experiment, it took him 8 seconds to replace the bung in the tube and start the stopwatch after adding the magnesium.

On the graph, sketch the curve that would be obtained if the results of this experiment were plotted. Label it **B**. [2]

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(d) Calculate the mass of the magnesium strip used in the experiment. [2]

$n(H_2) = 100 \div 24\,500 = 4.08 \times 10^{-3}$ mol (24.5 $dm^3\ mol^{-1}$ at 25 °C)

$n(Mg) = n(H_2) = 4.08 \times 10^{-3}$ mol

mass Mg = $4.08 \times 10^{-3} \times 24.3 = 0.0992$ g

Mass = 0.0992 g

(e) The rates of some reactions can be determined from the loss of mass over a period of time. However, the student said that he could not use this method as he only had a two decimal place balance. Is he correct? Justify your answer. [2]

Yes, he is correct, since the mass of hydrogen lost would be very small. The maximum mass lost is $4.08 \times 10^{-3} \times 2.02 = 8.24 \times 10^{-3}$ g, which would not give a detectable change on a two decimal place balance, so no graph could be plotted.

(f) He repeated the experiment using the same mass of magnesium and the same volume and concentration of acid, in order to collect 100 cm^3 of hydrogen, but over a longer period of time.

State **one** method of slowing down the reaction and use collision theory to explain this change of rate. [3]

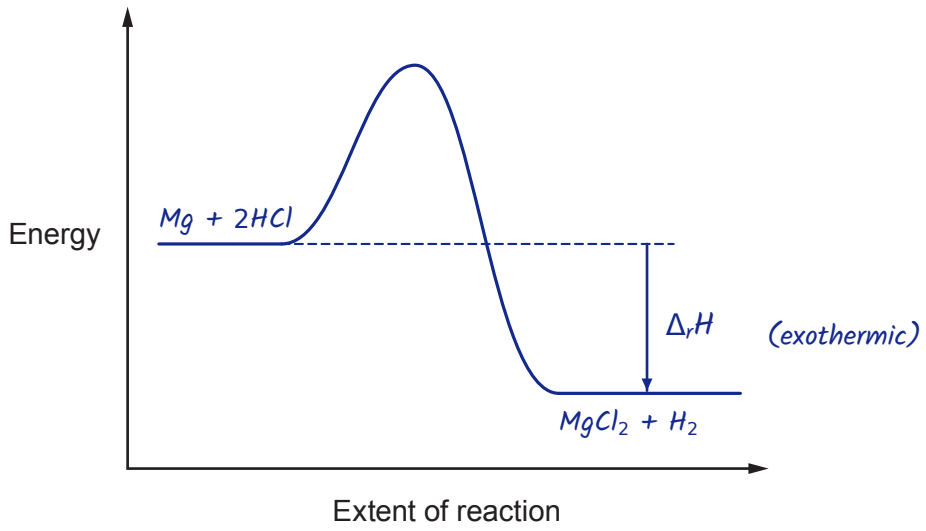
Decrease the temperature of the acid (e.g. cool it in an ice bath). The particles have less kinetic energy, so they collide less often and with less energy. Fewer particles have energy greater than or equal to the activation energy, so there are fewer successful collisions per second and the rate decreases.

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(g) On the axes below, sketch the energy profile for this reaction, labelling the enthalpy change of reaction, $\Delta_r H$. [2]



17

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